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TITLE OF THE INVENTION

IMAGE FORMING APPARATUS, METHOD AND DEVELOPING DEVICE TO OBTAIN A STABLE IMAGE DENSITY

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention relates to an image forming apparatus, method and developing device for use in image forming apparatus, such as copying machines, facsimile machines, printers, and so forth, and more particularly relates to a developing device capable of obtaining stable image density.

Discussion of the Background

In recent years, the use of digital type image forming apparatus, in which an image is formed on the basis of digital image data instead of analog image data has seen an increasing demand. In an image forming operation using digital image data, the density of pixels is not successive, i.e., the density of pixels occurs in a stepwise fashion due to the nature of digital data. Digital image forming apparatus using such digital image data are divided into two types, i.e., one type that expresses the density of pixels using two (binary) levels and another type that expresses the density of pixels using multiple levels.

SUMMARY OF THE INVENTION

Applicants have determined that the digital image forming apparatus of the type using two levels to express pixel density have drawbacks associated with developing devices usually found therein. Applicants have further determined that these drawbacks relate to the use of a developer-toner having a predetermined density that does not properly adhere to an

image portion on a photoconductor being used as a latent image bearing member. Not only does this toner not properly adhere where it should (i.e., an image portion), there is the further drawback that toner improperly adheres to a part on the latent image bearing member other than the image portion, i.e., a background portion, which results in forming an image not having proper pixel density and having a dirty background. Further, Applicants have determined that the developing performance of the aforementioned developing device changes depending on the environmental conditions found where the developing device is installed and/or after a period of time has elapsed which means that the dot in each pixel forming the image may not be stably formed.

The present invention has been made in view of the above discussed and other problems and addresses the above discussed and other problems. A preferred embodiment of the present invention provides a novel digital image forming apparatus of the type using two levels and a developing device for use in this digital image forming apparatus of type using two levels, as well as a method of developing a latent image capable of obtaining a stable density for the developed image.

According to a preferred embodiment of the present invention, an image forming apparatus includes a latent image bearing member having a photoconductive surface with a latent image including image areas, at least some of the image areas having different image potential values thereon and a developing device for performing a two-level developing operation with a one-component developer including toner particles. The developing device further includes a conveyor member to convey the one-component developer from a supply and to deliver the one-component developer with a predetermined charge to a developing region where a conveyor surface portion of the conveyor member is closely spaced from and

opposed to a photoconductive surface portion of the latent image bearing member, a thin layer forming device to form the developer on the developer-bearing member into a uniform thin layer, and a voltage source to apply a developing bias voltage to the conveyor member when the two-level developing operation is performed to move at least some of the one-component developer with a predetermined charge adhering to the conveyor surface portion to the photoconductive surface portion to form saturated amounts of the one-component developer on the image areas of the photoconductive surface portion wherein the saturated amounts do not charge with increases of the image potential above a predetermined threshold value to provide an image having a density determined by the saturated amounts.

In one aspect of the preferred embodiment, an adhering amount of the developer on the conveyor member is about 0.5 mg/cm^2.

In another aspect of the preferred embodiment, the developing region includes a developing gap formed to be equal to or less than about 150 μm.

In another aspect of the preferred embodiment, the absolute value of the predetermined charge of the one-component developer adhering to the conveyor surface portion is equal to or less than about 10 μC/g.

In another aspect of the preferred embodiment, substantially all of the one-component developer on the conveyor surface portion is moved during the forming of the saturated amounts.

In another aspect of the preferred embodiment, the developing bias voltage applied to the developer-bearing member is an AC voltage superimposed on a DC voltage with the AC voltage having a peak-to-peak voltage value of 600 to 1200 volts and a frequency of 2 to 6 kHz.

In another aspect of the preferred embodiment, the thin layer forming device protrudes a length of 10 to 15 mm.

In another aspect of the preferred embodiment, the thin layer forming device contacts the developer-bearing member with a contact pressure of from about 10 to about 150 g/cm.

In another aspect of the preferred embodiment, the developer-bearing member is provided with a surface roughness of from about 1 to about 4 μm RZ.

In another aspect of the preferred embodiment, the thin layer forming device forms a uniform thin layer having a height corresponding to 1 to 1.5 times a diameter of the toner particles.

According to still another aspect of the preferred embodiment of the present invention, an absolute value of the predetermined charge of the one-component developer is set equal to or less than about 10 μC/g.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the present invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings, in which:

Fig. 1 is a graph illustrating a developing gamma performance of a developing potential and an adhering amount of toner on a photoconductor drum in a developing device of the present invention when the adhering amount of toner on a developing roller is used as a parameter;

Fig. 2 is a drawing illustrating a schematic construction of the developing device of

the present invention;

Fig. 3 is a graph illustrating a relationship between a developing gap and a dot width in the developing device of the present invention when a developing potential is used as a parameter;

Fig. 4 is a graph illustrating a relationship between the developing potential and a dot area in the developing device of the present invention when a peak-to-peak voltage value of a developing bias voltage is used as a parameter; and

Fig. 5 is a graph illustrating a developing gamma performance of the developing potential and the adhering amount of toners in the developing device of the present invention when a charge amount of toner is used as a parameter.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of the present invention are now described in detail referring to the drawings, wherein like reference numerals indicate identical or corresponding parts throughout the several views.

Fig. 2 is a cross-section illustrating a developing device of a copying machine according to an embodiment of the present invention, which develops a latent image formed on an image-bearing member according to binary image information. The developing device includes a developing roller 3 acting as a developer conveyor member that conveys a toner 2 as a one-component developer to a developing region A, where the developing roller 3 has a surface portion opposed to a photoconductive drum 1 surface portion. The drum 1 serves as an image-bearing member. The developing device also includes a doctor blade 4 to form the toner 2 borne on the developing roller 3 into a uniform thin layer of the toner 2, and a toner-

supplying roller 5 to supply the toner 2 to the developing roller 3. The developing device includes a toner container 6 to contain the toner 2 to be supplied to the developing roller 3 by the toner-supplying roller 5, and an agitator 7 that conveys the toner 2 contained in the toner container 6 to the toner-supplying roller 5 while agitating the toner 2.

The toner 2 used in the developing device may be a non-magnetizable toner whose particle diameter is, for example, 5 to 7.5 μm. The toner includes resin materials, such as polyol resins, polyester resins, and styrene acrylic resins, to which charge control agents and additives are added. Salicylic acid may be used as the charge control agent, and silica, titanium oxide, and the like may be used as the additives.

As illustrated in Fig. 2, the developing roller 3 has a surface portion that is opposed to a surface of the photoconductive drum 1 at the developing region A. This developing region A includes a predetermined developing gap Gp to perform a non-contact developing operation. The preferable developing gap Gp may be 150 μm or less. Fig. 3 illustrates the results of an experiment performed to obtain a relationship between the developing gap and a dot width of a developed toner image, where Vp represents a developing potential. The results were obtained under the condition that a DC voltage was superimposed with an AC voltage having a rectangular waveform with a peak-to-peak voltage value V_{P-P} of 1200 V and a frequency of 2 kHz. The superimposed voltages were then applied to the developing roller 3.

As can be understood from the results when the developing gap Gp becomes larger than 150 μm, the dot width of the toner image falls below 30 μm when the developing potential was about 150 V, i.e., the dot width of the toner image becomes insufficient to form an image of good quality. The frequency of the rectangular waveform is preferably in a range from 2

kHz to 6 kHz.

Furthermore, in order to maintain the aforementioned developing gap Gp at a predetermined distance, disk shaped spacer rollers (not shown) having a radius larger than that of the developing roller 3 by the desired developing gap Gp can be arranged at both ends of the developing roller 3 on the same rotation axis as the developing roller 3, so as to contact surfaces of the photoconductor drum 1 at both ends thereof which are outside of the image forming area.

The surface of the aforementioned developing roller 3 may be preferably made of aluminum that is finished by a blasting process using fine uniform metal particles or glass particles. The preferable surface roughness of the developing roller 3 is 1 to 4 μm RZ, as defined by the JIS (Japanese Industrial Standard). That is, the diameter of a surface indentation on the surface of the developing roller 3 is 1 to 4 μm. This roughness of 1 to 4 μm RZ corresponds to 13 to 80% of the particle diameter of the toner 2. Accordingly, the toner 2 cannot be caught by the surface indentation and, therefore, the developing roller 3 smoothly conveys the toner 2. Furthermore, the surface of the developing roller 3 may be coated with resins so as to stabilize a quality of the surface of the developing roller 3 over a period of time. The preferable coating resins are, for example, silicone containing resins and Teflon containing resins. The silicone containing resins give good toner charging performance and the Teflon containing resins give good surface-releasing performance to the developing roller 3. In addition, even when the developing roller 3 has a partially coated surface (for example, the coating resins are put over the aluminum base metal at a certain covering ratio) and the aluminum base metal is partially exposed to the air, the developing operation can also be performed.

Furthermore, the developing bias voltage is applied to the above-described developing roller 3 at the developing gap Gp by a bias power source (not shown), causing the toner to move from the surface of the developing roller 3 to the photoconductor drum 1 across the developing region A. As described above, the developing bias voltage is an AC voltage superimposed on a DC voltage. The preferable value of the peak-to-peak voltage value V_{P-P} of the AC voltage is from 600 to 1200 V. As illustrated in Fig. 4, when the peak-to-peak voltage value V_{P-P} of the AC voltage falls below 600 V, the dot area of the developed toner image decreases resulting in deterioration of the image quality. On the other hand, when the peak-to-peak voltage V_{P-P} of the AC voltage exceeds 1200 V, electric discharging in the air may occur. As known by Paschen's law, the developing bias voltage should not be applied to cause a discharge in the developing gap Gp because this results in significant deterioration of the image quality.

The above-described doctor blade 4 protrudes from a blade holder (not shown) such that a lower surface of the protruded side portion of the doctor blade 4 contacts the surface of the developing roller 3, in a trailing manner relative to the arrow illustrated rotation of developing roller 3. The doctor blade 4 is made of material, for example, stainless steel of SUS 304 in the above-noted JIS and has a thickness of from 0.1 to 0.15 mm. Rubber materials, such as polyurethane rubber and resin materials, such as silicone resins, whose thickness is from 1 to 2 mm can also be used for the doctor blade. A preferable protruding length of the doctor blade 4 from the blade holder toward the developing roller 3 is from 10 to 15 mm. When the protruding length of the doctor blade 4 exceeds the upper limit (15 mm), the size of the developing device becomes large, resulting in the body of the image forming apparatus also becoming large. When the protruding length of the doctor blade 4

falls below the lower limit (10 mm), doctor blade vibration can occur due to friction between the blade and the developing roller 3. If the vibration occurs when a solid image is being formed, a lateral stripe can appear in the image. The preferable contact pressure of the doctor blade 4 relative to the developing roller 3 is from 10 to 150 g/cm. When this contact pressure exceeds the upper limit of 150 g/cm, an adhering amount of the toner 2 on the developing roller 3 decreases and a charging amount of the toner 2 becomes excessive. This causes a decrease in the amount of toner that moves to the photoconductor drum 1 from the developing roller 3, resulting in an unwanted lowering of the image density. When this contact pressure falls below the lower limit of the contact pressure (10 g/cm), the thin layer of the toner 2 is not uniformly formed on the developing roller 3 and coagulated clumps of toner 2 may pass between the doctor blade and roller 3 causing a significant deterioration of the image quality.

An elastic foamed layer is formed on the surface of the toner-supplying roller 5. The elastic foamed layer has numerous openings so that the toner 2 is borne in the openings to roller 3.

The agitator 7 supplies the toner 2 contained in the toner container 6 to the surface of the toner-supplying roller 5, and agitates the toner 2. However, when the toner container 6 is shaped such that the toner 2 is easily supplied to the surface of the toner-supplying roller 5 by its own weight, or the toner 2 has sufficient fluidity to be supplied to the surface of the toner-supplying roller 5 by its own weight, the agitator 7 may be omitted.

In the developing device described above, the agitator 7 supplies the toner 2 contained in the toner container 6 to the surface of the toner-supplying roller 5. The toner 2 supplied by the toner-supplying roller 5 is conveyed to a contacting part of the toner-supplying roller 5

with the developing roller 3 by rotation of the toner-supplying roller 5 in a counter-clockwise direction as illustrated by the arrow on roller 5 in Fig. 2. The toner 2 is charged by friction between the toner-supplying roller 5, the toner 2 itself, and the developing roller 3 at the aforementioned contacting part, and is supplied onto the surface of the developing roller 3. The toner 2 supplied onto the surface of the developing roller 3 is formed as a thin layer and is further charged by friction with the doctor blade 4 acting as a layer-thickness limiting member. Thus, the toner 2 is caused to adhere to the surface of the developing roller 3 with a desired amount of charge and with a desired layer thickness. The toner 2 is then conveyed to the developing region A by a rotation of the developing roller 3.

In the developing region A, the toner 2 on the surface of the developing roller 3 to which the developing bias voltage is applied from the bias power source (not shown) to form an electric field appropriate for the developing operation, moves back and forth between the surface portion of the developing roller 3 and the surface portion of photoconductor drum 1 at the developing region and thereby, an electrostatic latent image is formed on the surface of the photoconducting drum 1. Any of the toner 2 that does not adhere to the photoconductor drum 1 after passing back and forth through the developing region A is returned to the parts of the developing roller 3 because it corresponds to the non-image areas of the latent image on the surface of the photoconductor drum 1. This returned toner 2 is mechanically and electrically removed from the surface of the developing roller 3 by the toner-supplying roller 5. Furthermore, the charge on the developing roller 3 is made uniform by a charge generated by friction between the developing roller 3 and the toner-supplying roller 5, and the charge on the surface of the developing roller 3 is thus initialized to prepare for the next developing operation.

In such a developing device performing a developing operation according to two-level binary image density information for each pixel (hereinafter, referred to as a two-level developing operation), when the developing device develops an image with concentrated dots, such as when only two blank dots are available for every one writing dot in a 600 dpi (dots per inch) image writing operation, if the developing potential is changed, the dot area of the visible image on the photoconductor drum 1 may vary as described before.

To overcome this problem, a developing condition is set such that the amount of the toner 2 that adheres to the photoconductor drum 1 saturates when the developing potential exceeds a certain threshold value. Specifically, the image density is set to 1.5 as a target value when the amount of the toner 2 that adheres to the photoconductor drum 1 is 0.7 mg/cm^2. Accordingly, even if the potential is increased above the threshold value, the saturated amount of toner 2 adhering to drum 1 does not increase.

Fig. 1 is a graph illustrating a relationship between the developing potential and the amount of the toner 2 that adheres to the photoconductor drum 1 in the developing device of the present invention. Marks □ and Δ in Fig. 1 represent data obtained by an experiment in which the amounts of the toner 2 (m/a) that adhere on the developing roller 3 are set to 0.5 and 1.6 mg/cm^2, respectively. When the adhering amount of the toner 2 to the developing roller 3 is set to 0.5 mg/cm^2, between 1 to 1.5 layers of particles of toner 2 (the layers are 1 to 1.5 times as thick as the diameter of a toner particle) are formed on the developing roller 3. As shown in Fig. 1 by the marks □, the amount of the toner 2 that adheres to the photoconductor drum 1 saturates when the developing potential exceeds a certain value, i.e., about 200V. Therefore, an ideal two-level developing operation can be performed in which a predetermined density is obtained without producing an image having a dirty background.

On the contrary, when the adhering amount of the toner 2 to the developing roller 3 is set to 1.6 mg/cm^2, 3 to 4 layers of the toner are formed on the developing roller 3. As shown in Fig. 1 by the marks Δ, since all of the layers of the toner do not move with the same predetermined developing potential, when the developing potential is increased, the developing amount, i.e., the amount of toner that moves to the photoconductor drum 1 from the developing roller 3, increases as the developing potential is increased. Accordingly, the developing amount varies with a potential variation on the photoconductive drum 1 due to a change of an output of an optical writing system. Therefore, a stable image density cannot be obtained since the amounts of toner deposited are not saturated relative to a threshold potential value.

Fig. 5 illustrates a developing gamma characteristic for two types of toners 2 having different charging amounts (g/m). Marks ◇ and □ in Fig. 5 represent data obtained for a high charging amount toner 2 having the charging amount (g/m) of -13 μC/g and a low charging amount toner 2 having the charging amount (g/m) of -8 μC/g, respectively. As can be understood from the data in Fig. 5, the amount of the toner 2 that adheres to the photoconductor drum 1 increases until the developing potential reaches approximately 300 V for the toner 2 having the charging amount (g/m) of -13 μC/g, while the amount of the toner 2 that adheres to the photoconductor drum 1 saturates at the developing potential of approximately 100 V for the toner 2 having the charging amount (g/m) of -8 μC/g. Thus, when an absolute value of the charging amount "g/m" of the toner 2 becomes relatively high, the developing amount changes due to an influence of a change of the potential of the photoconductor drum 1 resulting in a change of image density. On the other hand, it has been determined that when the absolute value of the charging amount is equal to or less than about

10 μC/g, the opposite holds time.

As described above, when a two-level developing operation using a one-component developer is performed under the condition that the amount of toner 2 adhering to a photoconductor drum 1 saturates when the developing potential exceeds a certain threshold value, a stable image density can be obtained regardless of environmental condition and even after a period of time elapse, without producing an image having a dirty background.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

This document claims priority and contains subject matter related to Japanese Patent Applications No. 11-079824, filed on March 24, 1999, and the entire contents thereof are herein incorporated by reference.